

Original Paper

The Use of Desalination Technologies to Alleviate Water Shortages in Sub-Saharan Africa (SSA): Challenges and Recommendations

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Abstract

Water scarcity is a major and growing problem in SSA. A SSA country (South Africa) has adopted desalination as a strategy for dealing with water shortages; while the construction of new desalination plants have been proposed in some others (Ghana, Namibia and Cape Verde). This review paper examines the use of desalination technologies for augmenting supplies in sixteen SSA countries, using data derived mainly from published literature. Results reveal that the usage of desalinated freshwater to augment supplies in the region is relatively recent; however the usage is on the increase, especially in countries with arid climate. Several factors including massive failures of public water supply systems, increases in the demand for freshwater, rapid and high rates of urbanization, population growth and the reoccurring droughts account for increases in the demand for desalination technologies in SSA. Many critical issues and constraints make the desalination option neither the most feasible nor a priority for water supplies within the humid parts of SSA. The paper recommends that for quality and sustainable service delivery to be attained in the region, governments should develop alternative freshwater sources, address infrastructural decay, employ new management strategies in the water sector and distribute water infrastructure equitably.

Keywords

seawater desalination, water shortages, rural communities, sub-Saharan Africa, management strategies, options

1. Introduction

Desalination is a process of removing salt from salty water, like sea water (Dawound, 2006). In the process, saline brine which is usually discharged into the sea is produced (Salet, 2008). Salty water is desalinated primarily to produce freshwater for human consumption or irrigation. Modern interest in the use of desalination strategy for sourcing freshwater is based on the fact that the strategy, unlike other alternative freshwater sources, is environmental friendly (Okoye, 2015). Areas of intense desalination activities currently include the Arabian Gulf, the Mediterranean and the Red Sea region as well as the coastal areas of California, China and Australia (Akili et al., 2008). The world's leading countries by desalination capacity in 2012 were the United Arab Emirates (35% of the world sea desalination capacity), Saudi Arabia (34%), UAE (16.2%), Spain (6.4%), Kuwait (14%), Qatar (8%), Bahrain (5%) and Oman (4%) (Dawoud & AIMulla, 2012). The steady increase in the usage of seawater desalination has demonstrated that this option is feasible in many areas.

Desalination is very relevant in areas where moisture availability is critical and where access to freshwater is by no means certain for many households (Akili et al., 2008; Allaire, 2009). In SSA, shortages of potable water are critical development challenges confronting most countries (Nzeadibe & Ajaero, 2012) access to potable water in many SSA countries is by no means certain due to a variety of factors such as periodic droughts, limited availability of and pollution of available freshwater sources (Calow et al., 2010). Shortage of natural freshwater supply constrains socio-economic growth and development in many parts of SSA (Fotso et al., 2007). It constrains the regions' efforts towards poverty reduction, economic growth and food security (UN, 2010). It hinders domestic activities and agricultural production in the region, especially in areas which suffer from *periodic droughts* (Calow et al., 2010).

Satterwaite (2016) showed the disastrous performance of many SSA countries in relation to the goal of halving the proportion of the population without access to improved drinking water sources between 1990 and 2015. His analysis showed that of the 25 countries with the highest proportion of their population lacking access to improved water sources, 23 were in SSA alone. Most countries in the region fell short of the Millennium Development Goal (MDGs) target 7 of reducing by half the proportion of people without sustainable access to safe drinking water and basic sanitation by 2015 (Omole et al., 2015). In many households in the region, especially in rural areas, residents suffer from water supply inadequacies; a situation which is compounded by rapid increases in population, conflicts and high levels of poverty (Omole, 2015). The 2015 WHO and UNICEF report showed that in many communities across the region, the population remains severely underserved (WHO & UNICEF, 2015). SSA currently lags behind many other developing regions (Oceania, Southeast Asia, southern Asia, Latin America and Eastern Europe) in access to safe drinking water (WHO & UNICEF, 2014). For instance, Latin America and eastern Europe experienced rapid progress in delivering potable water to their people prior to 2015 (Zeraebruk et al., 2014). Most countries in these regions met the 2015 Millennium Development Goal's target of halving the proportion of its people with regular access to

potable water before 2015. In 2013, 71% of people of Latin America had adequate access to clean water (WHO & UNICEF, 2014); a period when most households in rural communities of SSA were using unprotected water supply sources (Adeleye et al., 2014; Omole et al., 2015). Water supply shortages in SSA has been a subject of critical investigation by scholars, since the International Decade for Drinking Water Supply and Sanitation Decade of the 1990s (Goni, 2006). Undoubtedly, many of the investigations have been of great value in identifying areas in which the policies and practices of the supply agencies have resulted in clear inefficiencies in capacity development (Olaleye, 2010). Many of these investigations also have stimulated changes in the approaches to water supply by state authorities. However, most of the investigations according to Adeleana et al. (2006) and Cherlet and Venot (2013) have focused mostly on issues such as water system development, system management, institutional strengthening, pattern and problems of water supply, supply policies, water distribution patterns and water quality. Preoccupation with the above have diverted researchers' attention and research activities from other equally, and perhaps more critical issues, three of which are considered in this paper; (1) the current service coverage with regards to the use of desalination technologies to alleviate water shortages in SSA, (2) why the desalination option is a necessity in some SSA countries and not in others, and (3) and the policies and strategies which can improve the quality and sustainability of supplies in countries where desalination is neither a priority nor the most feasible option.

This review paper seeks to provide answers to the above questions and, in addition, suggests strategies for reducing water shortages in areas where desalination is neither a priority nor the most feasible option. The data used in this review were collected mostly from published literature-journals, books, document analysis, the internet, project reports; mission reports of pilot studies relating to water projects and from relevant records of national and state water agencies. The result of this work will contribute to the knowledge base for future research and water resources development in the SSA.

1.1 Theoretical Literature Review

A variety of desalination technologies have been developed in the last few decades. The first forms of desalination plants (built mostly in the Middle East) were developed on the basis of thermal distillation technology, where salty water was heated until it evaporates and then condensed to produce freshwater (Dawound, 2006). This technology requires a lot of energy. Plants built more recently tend to be based on Reverse Osmosis (RO) processes; where salty water under high pressure is forced through a semi-permeable membrane (Okoye, 2015). The salt stays behind while the water goes through. This is the most energy-efficient desalination technology presently in use across the globe (Carlson et al., 2010). The variants of desalination technologies which are generally adopted for the conversion of saline water into freshwater are summarized in Table 1.

Table 1. Variants of Desalination Technologies

<i>Desalination Technologies</i>	Sub Types	Description
Reverse osmosis technology	Nanofiltration, separation, Forward osmosis, etc.	Membrane This involves separating water molecules and salt ions and forcing the former to flow out through a semi-permeable membrane barrier which stops salt.
Freezing <i>desalination</i>	Freezing <i>desalination</i>	Freezing water removes salt from ice; ice, when melted yields pure water.
Solar <i>desalination</i>	Solar humidification-dehumidification, multi-effect humidification, etc.	This involves using solar heat to vaporize sea water and cooling the vapor to get pure water.
Electro dialysis <i>Method</i>	Methane hydrate crystallization	This involves separating water molecules and salt ions by electricity rather than heat.

Sources: Grag (2007), p. 921; Paisley (2017), pp. 12-13.

The processes and technologies involved in the above methods are discussed in details by Grag (2007), chapter 19: pp. 921-952, and in Akili et al. (2008), p. 4.

Desalinated freshwater is currently produced in various countries (Baguma et al., 2013). Summary information on the major producers of desalinated water currently is shown in Table 2.

Table 2. Major Producers of Desalinated Water across the Globe in 2017

S/N	Country	No of plants	Plant Location(s)	Yr Opened	Mean Capacity of plants in m ³	Mean Cost of producing m ¹ of water	Difference B/W the mean cost in South Africa (\$1.00-\$1.15)
1	Israel	4	Hadera, Palmahim, Ahkelon, Sorek	2005	120 million m ³ /year	\$0.40	\$0.40-\$0.75
2	Saudi Arabia	32	Shoaiba, Jubali, Rabigh, Yandu, Obhor, etc.	NA	800,000 m ³ /day	\$0.49	\$0.51-\$0.750
3	United Emirates	Arad 12	Kalba, Layyah, Khor, Fakkan, Ghaliah, Fujairah, etc.	2010	90,000 m ³ /day	NA	
4	United States	45	Texas, California, Florida, Arizona, etc.	2001	NA	\$0.46	\$0.54-\$0.75
5	United Kingdom	NA	Beckton (east London), Jersey, etc.	1970	6,000 m ³ /day	NA	
6	Qatar	3	Ras Abu fontas	NA	160,000 m ³ /day	NA	

7	Spain	13	Lanzarote, Tordera, Barcelona, Oropesa, etc.	1964	85,000 m ³ /day	NA	
8	Iran	NA	Tehran, Shiraz, etc.	2015	400,000 m ³ /day	NA	
9	India	NA	Minjur, Nemmmmeli, etc.	NA	36.5 million m ³ /year	\$0.49	\$0.51-\$0.75
10	Oman	6	Muscat, Sohar, Sur, Qarn Alam, etc.	2004	15,000 m ³ /day	NA	
11	China	NA	Tianjin near Beijing	NA	200,000 m ³ /day	NA	
12	Egypt	5	Dahab, Hurgad a, Oyoun Moussa, Zaafarana,etc.	1999	NA	Between \$0.50 and \$1.00	\$0. \$0.50-\$0.15
13	Bahrain	5	Al Hidd, Durrat, etc.	2000	36,000 m ³ /day	NA	
14	Chile	NA	Capiapo, Thorium, etc.	NA	2000 m ³ /day	NA	
15	Australia	6	Sydney, Victoria, Adelaide, Perth, Gold Coast, etc.	1997	NA	NA	
16	Algeria	15	Arzew, Tenes, Fouka, Skikda, etc.	NA	100,000 m ³ /day	Between \$0.50 and \$1.00	
17	South Africa	6	Knysna, Plettenberg Bay, Lambert Bay, Cannon rocks, etc.	NA	15,000 m ³ /day	Between \$0.50 and \$1.00	
18	Hong Kong	NA	Tuen Mum, Ap Lei Chau, etc.	2014	50 million m ³ /year	HK\$8.2	

Sources: (1) Mahamed and Mulla (2012); (2) Paisley (2017).

As shown in Table 2, most desalination plants are located in dry countries—the Middle East, North Africa, Australia, United States and Eastern Asia. Israel is particularly renowned in artificially producing freshwater. Israeli desalination technologies provided 40% of the country's national water requirement in 2015 and are expected to supply 70% by 2050 (Paisley, 2017).

The steady increase in the usage of seawater desalination has demonstrated that this option is feasible in many areas, including SSA.

1.2 The Study Region

SSA occupies much of Africa south of the Sahara Desert (Cherlet & Venot, 2013). The region extends from about 15° N. to 35° S. of the Equator (see Figure 1) (Hayson, 2009). The climate of the region is tropical, with high temperatures and high humidity as well as marked wet and dry seasons, though there

are variations between parts (Ajayi & Abegunrin, 1994). Rain falls unevenly over the region. Some areas get little or almost no precipitation, while others, like the Democratic Republic of Congo (DRC) are among the most water-rich countries on earth (Dapaah-Siakwan & Gyau-Boakye, 2000). Almost every area in the Congo Basin experience high precipitation levels, with some parts receiving heavy precipitation almost daily. An interesting feature of the rainfall patterns in much of SSA is its variability, with coefficient of variation for mean monthly rainfall usually exceeding 35% along the Gulf of Guinea. This pattern together with the seasonal variation of water availability combined with the phenomenal growth of the population creates two important scenarios in the water use pattern (Awunh et al., 2009). First, direct collection and use of rain water is more pronounced in the rainy season. Second, extraction of water from springs, streams, ponds and wells as well as water shortages are more common during the dry season.

All the countries of SSA are independent states. SSA is ethnically diverse, with about 200 tribes speaking over 50 different languages, inhabiting the Congo Basin alone (Dapaah-Siakwan & Gyau-Boakye, 2000). The countries that make up SSA are a mix of resource rich and resource poor, but generally lack adequate access to quality and sustainable water services delivery (Adeleana et al., 2006). Majority of the countries in the region have agriculture as their primary source of livelihoods (Hunter et al., 2009). Currently the region has a population of more than 1.37 billion people (Paisley, 2017). The Rift valley areas and coastlands of west and east Africa are fairly well populated owing to their climate which is favorable to agricultural production (Babic et al., 2014). Much of the other areas, being largely arid are sparsely populated; Kalahari Desert is almost uninhabited.

2. Methodology

The primary aim of this research is to examine the natural and human factors that promote and/or retard the use of desalination strategy to improve access to rural water supply in SSA and to suggest options for addressing water shortages in states where desalination is not a necessity or the most feasible option for rural water supplies. Data were collected through extensive desk research on published documents and from relevant records at national and state water agencies. The information were synthesized to identify the patterns and trends in the use of desalination technologies in SSA sub-region as well as in assessing the other options for achieving sustainable rural water services in the study area. Sixteen SSA countries were purposefully selected and used for the study. Only countries that are water-stressed, located along the coast, have functional/proposed desalination plants or have documented information on factors limiting or enhancing the use of desalination technologies were selected. Based on these criteria, the countries shown in Figure 1 were selected and used in the study. The data collected were analyzed through the use of percentages.

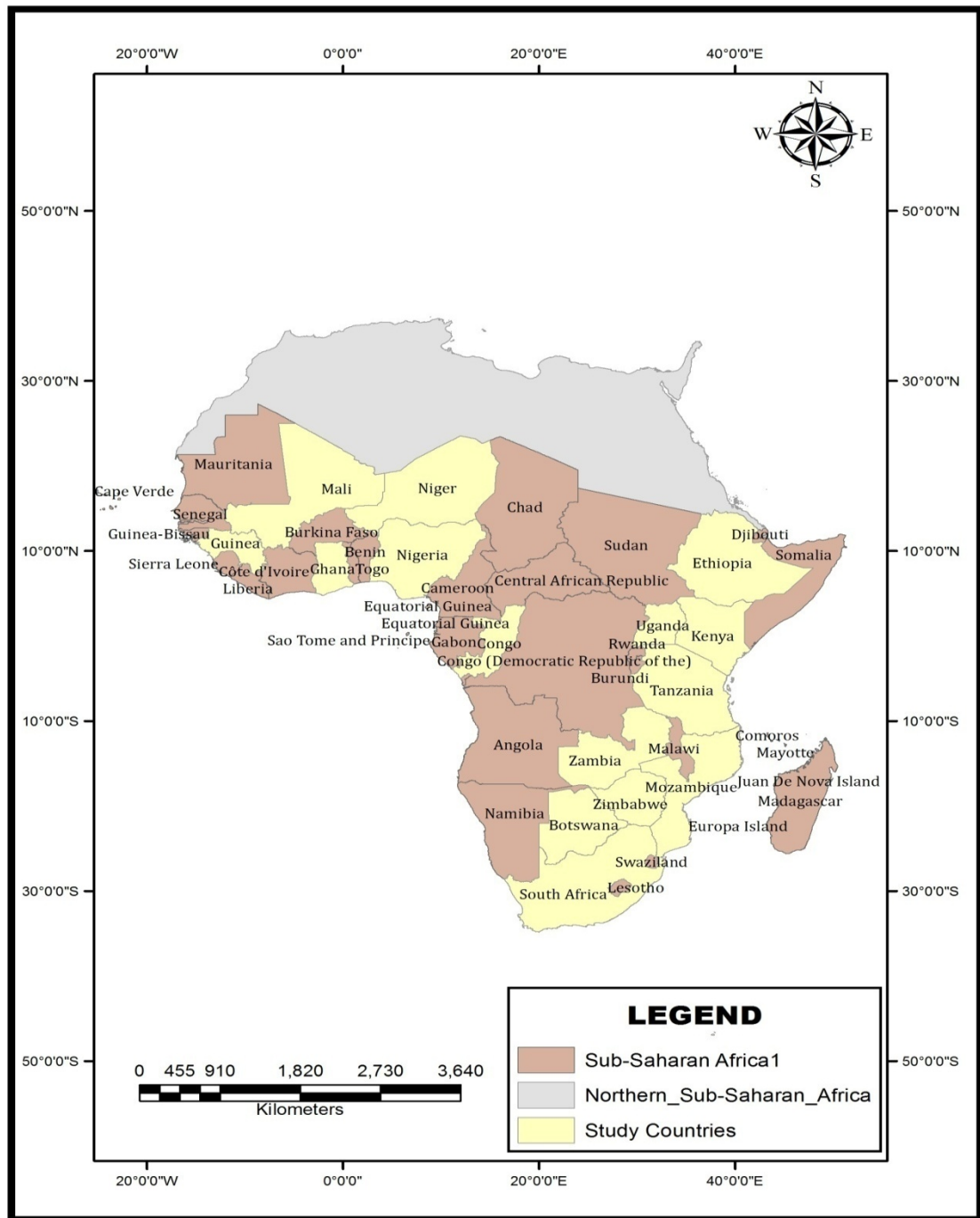


Figure 1. Sub-Saharan Africa, Showing Location and Countries Used in the Study

Source: GIS Unit, Department of Geography. University of Nigeria, Nsukka.

3. Results

3.1 Current Service Coverage of Countries Where Desalination Technologies Have Been Developed or Proposed

Desalination technologies have been developed in and are currently being used to augment household water supply in South Africa and have equally been proposed for Namibia, Ghana, Niger Delta and Cape Verde. These countries and regions are briefly described below:

1) South Africa

South Africa occupies the southern tip of Africa, from the desert border with Namibia on the Atlantic coast southwards around the tip of Africa and then north to the border with Mozambique on the Indian Ocean (Carden & Armitage, 2012). Geographically the country lies between latitude of 29°00' S and longitude of 24°00' E. Many of the provinces in the eastern and in the North Western parts of the country are water-stressed because of scanty rainfall and arid climate (Pavelic et al., 2012). The existing rivers and streams are generally over-drawn. For instance, the mean dam levels in Western Cape fell from 53.4% in 2001 to 38% in 2017; and again to 25.3% in January 2018 and to 24.5% in May 2018 (Reuters, 2018). The water-stressed areas in the country are largely semi-arid due to their geography and droughts in such areas, specifically in the Western Cape, are cyclic and are even predicted to intensify due to climate change (Chukwu, 2015). South Africa relies heavily on desalination technologies to improve access to water services delivery. Desalination plants have been built in most of the water-stressed provinces of the country to augment available water resources (Pearson et al., 2015). Currently, South Africa has ten desalination plants (dotted along the coast from Lambert's Bay in the West to Richard's Bay in the East) supplying desalinated freshwater to approximately 12.3% of the population; and several new plants under construction in Durban and Cape Town (Reuters, 2018). Fortunately, South Africa has a relatively strong and stable economy that can finance/sustain the desalination option.

2) Namibia

Namibia has a surface area of 824,292 km² and lies between latitudes 22°00 and 22°31S and longitudes 17°00 and 17°41 E (Taylor, 1996). The country stretches for about 1,300 km from south to north and varies from 480 to 930 km in width from west to east. Namibia, like other major producers of desalinated water (Israel, Australia, China, and United States, etc.) is a dry, coastal country with a desert climate. The Namib Desert stretches along the whole west coast of the country, while the Kalahari Desert runs along its southeastern border with Botswana. Sustainable natural freshwater sources in the country are few and far between (WAF, 2012). Fortunately, Namibia is an oil-rich, relatively wealthy country and can afford the high energy cost of desalination plants. Currently desalination plants are under constructions in both the western and southeastern parts.

3) Cape Verde

Cape Verde is another area in SSA where the desalination option is both a priority and feasible. Cape Verde is a tiny, west most island and country in West Africa, located in the Atlantic Ocean, nears the

coast of Guinea. The island is dry, of volcanic origin and has limited water supplies. A desalination plant to serve the island, promote its thriving tourist industry has been proposed by donor agencies in the country (Cherlet & Venot, 2013). Although the country is not wealthy, donor agencies have pledged to assist with the cost of providing a desalination plant in the area (Pearson et al., 2015).

4) Niger Delta region (Nigeria)

The Niger Delta region of Nigeria has ample water source of $104 \text{ km}^3 \text{ yr}^{-1}$ of surface water and 21 million $\text{km}^3 \text{ yr}^{-1}$ of groundwater (Ajayi & Abegunrin, 1994). However the inability to harness and treat the highly polluted water and make it available for use in the region, accounts in part, for the persistent call for the establishment of desalination plants in the region (Okoye, 2015). The region is a water-rich area but the surface and ground water resources of the region are highly polluted by oil spillage/exploration (Okoye, 2015). In addition, persistent and heavy effluent wastes discharge to nearby streams from the numerous industrial plants in the region create an unending need for artificially generated freshwater resources for the residents (Nwankwo, 2014). Also, because of the oil economy, the region can afford the high energy cost of desalination plants.

5) Ghana

Ghana has a surface area of about $239,460 \text{ km}^2$ and is situated on the west coast of Africa between latitudes $4^\circ 44' \text{ N}$ and $11^\circ 15' \text{ N}$ and longitudes $1^\circ 12' \text{ E}$ and $3^\circ 15' \text{ W}$ (Imoro & Fieldman, 2011). Ghana is well-watered with high annual rainfall varying from 800 to 2,200 mm (Cherlet & Venot, 2013). It has a dense system of rivers and streams. The country's surface water resources are however concentrated, mainly in three main river systems in the southern parts of the country (Apambire et al., 1997). The northern parts of the country experience prolonged dry seasons of about 7 months with very high evaporation losses; this leads to the drying up of many surface water bodies (Majuru et al., 2011). This makes surface water supplies unreliable and insufficient to meet the water demands for socio-economic development. Because of this, the constructions of new desalination plants have been proposed for northern Ghana (Paisley, 2017) where, water scarcity is a major and growing problem.

3.2 Natural and Non-Natural Factors Which Make Desalination a Necessity in the above Countries

The natural and non-natural factors which make desalination a necessity in the above countries are summarized below:

1) Climate and lack of alternative freshwater sources

Desalination is a necessity in the above countries because moisture availability is critical and access to alternative freshwater sources is by no means certain for many households, especially in rural areas (Akili et al., 2008; Allaire, 2009). Shortages of natural freshwater supply in these countries occur due to desertification and consequent over withdrawal of water from the groundwater aquifers (Nzeadibe & Ajaero, 2012).

2) Droughts

Apart from the Niger Delta, the areas mentioned above are largely semi-arid and drought-prone regions; where freshwater is scarce and where limited volumes of available water hinder domestic activities and

agricultural production (Callow et al., 2010). The worst affected rural communities are located in northern Ghana and Namibia (Cherlet & Venot, 2013). Droughts in these countries are often cyclic and land use practices exacerbate their effects (Fotso et al., 2007). Because of frequent droughts, many of the rural people in Namibia, Ghana and Cape Verde lack access to potable water (Adelona & Mac Donald, 2008; Allaire, 2009).

3) Pollution of local water sources

Surface water pollution occurs widely in the Niger Delta region of southern Nigeria. Several factors including nutrients, sediments and other pollutants from point sources and non-point sources, airborne pollutants, contaminated sediments and physical or habitat degradation are causing the impairment of rivers, streams and lakes in the region (Metwaky et al., 2006). Many of the regions' surface water receive huge quantities of untreated wastes (industrial effluents, domestic, hospital and commercial wastes) which contain substances that are not only harmful to humans but also to aquatic biota (Adekalu et al., 2009). As a result the quality of surface water continues to decline in the region. Water quality deterioration reduces the total amount of water available for use by the human population and creates enormous environmental and public-health problems (Metwaky et al., 2006). Because of this, calls for the construction of desalination plants in Rivers and Bayelsa States have been made by private and public agencies (Okonkwo et al., 2011; Nwankwoala, 2011).

3.3 The Situation in Other Sampled SSA Countries

Despite the popularity of the desalination technologies, especially in the Middle East and the Gulf region, evidences from our study area suggest that outside the five areas discussed above (South Africa, Namibia, northern Ghana, Cape Verde and the Niger Delta region of Nigeria), the desalination strategy is not a priority in the other SSA countries (Whittington, 1998; Zeraebruk et al., 2014). The strategy may not deliver satisfactory levels of sustainability in household water delivery as in the Gulf region. There are a number of reasons why previous workers in the water supply sector rated the suitability of desalination technologies in the other SSA countries very low. These reasons include:

1) Geographical location

Many of the countries (Mali, Burkina Faso, Chad, Niger, Botswana) with the biggest water shortage problems are located deep in the interior of the continent, thousands of miles or kilometers away from the nearest coast (Adelona & Mac Donald, 2008). For instance, Niamey (Niger), is over 1643 kilometers away from the Atlantic coast (Pritchard, 1981). The cost of transporting water over this distance, added to the desalination costs will undoubtedly be uneconomical, i.e., be higher when compared to the cost of developing alternative (groundwater) sources or of transporting freshwater from somewhere else. Most desalinated water producing cities such as Sidney (Australia), California (United States), Beijing (China), Larnaca (Cyprus), Tripoli (Algeria), Jubal (Saudi Arabia), etc., are coastal cities. The dominant cost is the desalination, not transport (Dawound, 2012).

2) *Relief*

Many water-stressed communities in SSA such as Harare (Zimbabwe), Bamako (Mali), and Addis Ababa (Ethiopia), are not only deep in the interior of the continent but are also cited on elevated highlands with difficult terrains (Carlson et al., 2010). In such areas one needs to lift the water to the highland locations. In places like Kenya, Tanzania and even in Nigeria (Jos), this implies lifting water to about 2,500m or 6,400 feet (Hayson, 2006; Marks et al., 2015). The costs of lifting water to such high elevations may make the whole thing uneconomical.

3) *Settlement pattern*

Desalination may be a solution for water shortages in clustered, water-stressed communities, but not for communities with scattered and isolated houses (Marks & David, 2012). Unfortunately, many rural areas in SSA are characterized by scattered households; often located in remote, inaccessible hillsides, forests, and/or on wide plains or plateau-like surfaces (Makoni et al., 2014). In South Africa, for instance, approximately 6% of the national population lives in scattered patterns (Carlson et al., 2010). In Kenya and Tanzania, many small rural settlements are located in mountainous and inhospitable areas (Nkotagu, 1996). The cost and skill required to access/install, operate and maintain desalination plants or transport artificially-produced water to such areas will make the strategy uneconomical.

4) *Limited Technologies*

Desalination technologies are complex, highly technical and expensive (Van Rooijen et al., 2009). Currently, nuclear technology is used to produce large amounts of artificially desalinated water in various countries. From Asia (China, India, Russia, and Japan), through Europe and Australia nuclear reactors linked to desalination plants are operating (Paisley, 2017). The high levels of scientific and technical capacity/skills which are major catalysts for developing desalination technologies are still lacking in SSA countries.

5) *Availability of cheaper, alternative freshwater sources*

Some of the sampled countries (such as those located near the coast or in the Congo Basin) experience high precipitation levels, with some places in the Congo Basin receiving heavy precipitation almost daily (Dapaah-Siakwan & Gyau-Boakye, 2000). This rainfall pattern together with the abundant surface and groundwater resources make the production of artificial freshwater unnecessary as cheaper, alternative freshwater sources exist.

6) *Shortage of finance*

The cost of desalinating sea water is higher than many alternatives including water recycling and sourcing freshwater from rivers, groundwater and through water conservation (Bhatia, 2009). These alternatives are generally available in the other sampled SSA countries. Desalination processes and facilities have high cost implications. For instance, the purchase and installation of facilities, sourcing of sea water, labour, energy, wastes disposal, etc., involves costs which must be met in order to artificially produce water. Desalination is also only energy intensive; the structures are often large, expensive and involve major public and/or private infrastructure planning and coordination (WAF, 2012). The costs of

both energy and technology required may not be within the reach of the sampled countries due to wide-spread poverty.

7) Legal Issues

Many of the sampled countries are landlocked and, as such, the conveyance structures transporting water from the sea to cross border based destination plant locations must pass through another country (Pritchard, 1981). Projects of this type can be complicated in legal terms, since water and riparian rights are affected; this is especially true if the countries involved have been having friction. The legal handles involve may delay, prevent and/or alter the initial costs and size.

3.4 Policies and Strategies Which Can Accelerate Water Supply Sustainability in SSA Countries Where Desalination Technologies Are Not Appropriate

The analysis in this section is concerned with the policies and strategies that can accelerate progress in the quality and sustainability of water supply in sampled countries where desalination is not appropriate. A distinction is made between the options proposed for short term objective of reducing water poverty and scarcity and the long term aim of promoting quality and sustainable water supplies and wider access in the region. In the short term, water sources, supply systems and water infrastructure are relatively fixed; over the long term, however, they can be adjusted, extended, remodeled and/or new sources, supply systems and infrastructures can be developed.

1) Short to Medium term Options

The fundamental concern here is with how to reduce water poverty by constraining increases in water shortages over a time frame in which existing water sources, supply systems and water infrastructure are relatively fixed. Previous workers have noted that supply projects in SSA are characterized by poor performance (Adeleye et al., 2014) and most water users are facing serious and persistent challenges in meeting their water needs. So, in the short term, what are the strategies which can constrain water shortages within this time frame? Within the short time-frame, the problem of frequent and premature collapse of water infrastructure which is widespread in the region can be tackled through effective community participation, provision of spare parts, funds, local resources mobilization, use of quality infrastructure and ad-hoc governments'-sponsored programmes aimed at halting the deterioration of water infrastructure and service breakdowns.

Water poverty in SSA can also be reduced (in the short term) through efficient management of available water resources. Management, as used here, refers to activities carried out in connection with daily operation of water supply systems, including financial matters (billing, collections and purchase of spare parts) and repairs water projects components (Chitonye, 2011). Efficient water management helps to improve, sustain or extend water supply facilities so as to improve users welfare by increasing the number of users or the total quantity of water delivered to users (Olaleye, 2010). Community-based management, with external support, is believed to keep systems running sustainably once they are installed (Lockwood et al., 2003). To reduce water poverty and improve, sustain or extend water supply service in rural communities, in SSA, water supply institutions and service providers need to manage

water projects efficiently. This is necessary in order to solve present and future problems as well as to minimize systems breakdowns and extend the life span of water infrastructure (Baguma et al., 2013).

2) Long-term Options

Our interest in this section is on the strategies which the sampled countries can adopt, in the long-term, to accelerate access to potable water, especially in the semi-arid, remote, water-stressed, landlocked countries where desalination is neither feasible nor appropriate. Pavelic et al. (2012) and Eva et al. (2015) reported that quality and sustainable water supply still remains an acute problem in most of these countries due to wide-spread water infrastructural decay and frequent system breakdowns, among other factors. Literature evidences show that variations in national water supply policies have led to the adoption of varied strategies to accelerate access to potable water in these countries (Gbadegesin & Olorundemi, 2007; Abaje et al., 2009; Pavelic et al., 2012). Tackling the problems of water crisis and reducing shortages in the sampled countries of SSA in the long-term requires new thinking; new policies and strategies. Water services providers in these countries can overcome the problems of water crisis and reduce shortages through more investment in water infrastructure, appropriate policies instruments, and by ensuring the sustainability of water infrastructure. These options have been proposed in our recommendations to achieve the *long-term objective* of accelerated increases in the level of access to potable water.

4. Discussion

The issue of water crisis and water shortages in SSA is well known (Omole et al., 2015). Water users in most countries of SSA face serious and persistent challenges in meeting their water needs. Water systems failures occur widely in the region, especially in rural areas (Adeleye et al., 2014). The factors which occasion the massive failures in the water systems vary spatially and temporally. In South Africa, for instance, Pavelic et al. (2012), Marks et al. (2013) and, Eva (2015) attributed the mass failures in the water systems to inadequate technology and skills as well as to the shrinking service providers' budgets. A study undertaken in 2006 revealed that an additional 1,100 municipal plumbers were needed countrywide in order to cope with operation and maintenance of water service infrastructure. Furthermore, local municipalities were found to be operating with an average of 2 civil engineering professionals per 100,000 population which is far below the prescribed 5 civil engineering professionals per 100,000 population (Marks et al., 2013).

In Uganda, Kenya and Tanzania many rural water service providers are struggling with critical deficiencies arising from the use of old and deteriorating infrastructure; weak institutional framework, poor governance structures, lack of resources (particularly financial resources) and a lack of capacity (including properly trained personnel and with required skills) (Nkotagu, 1996; Carter & Rwamwnja, 2006). The lack of resources and capacity often forces service providers to focus more on activities necessary to deliver immediate services, while preventive maintenance (Eva et al., 2015) which involves activities that may keep the system in long-term good operating condition are neglected.

In Zimbabwe and Ethiopia service provision is severely constrained by inadequate technical capacity required to implement a sustainable operational and maintenance systems of water infrastructure (Makoni et al., 2004; Zeraebruk et al., 2014). Consequently, piped water supply systems have not been able to meet the demand for potable water in both urban and rural areas.

The solution to water supply inadequacies in the region lies more in efficient and sustainable development of alternative, cheaper sources of freshwater and water systems maintenance than in the use of desalination technologies. The desalination option is neither a necessity nor a feasible option for tackling the problems of water shortages in many of the sampled countries. Many factors, including inadequate capacity, shortage of relevant skills, finance, and long distances from the sea, relief, legal huddles, and dispersed settlement patterns make the desalination strategy a low value option in the region's water supply sector. The efficacy of this assertion has been investigated in many parts of the developing world and the outcome of many of the studies attest to the reality of the statement (Nkong, Pender, & Koto, 2008). Based of this, service providers in the sampled areas need to concentrate on alternatives freshwater sources such as abstraction from rivers, groundwater aquifers, water recycling and water conservation. Fortunately, these alternatives are generally available, in varying degrees, in the study area. For instance; the SSA countries within the Nile mega basin as well as those in the Gulf of Guinea and central Africa are blessed with abundant seasonal rainfall and surface water resources. The surface water resources endowments of this area include over 17,000 miles of named rivers and streams, 3,623 named lakes, 690 flowages and 312,689 acres of wetland (Jasper, 1976; Babic et al., 2014). The big rivers including the Nile (4,000 miles), Niger (2,300 miles), Zambezi (1,899 miles), Congo (3,000 miles), Benue, Senegal, Orange, Limpopo, etc., are perennial and dynamic river resources (Jasper, 1976). Similarly; the Sahel region (Mali, Niger, Chad, and Burkina Faso) has abundant groundwater reserves (Pavelic et al., 2012). Majority of the residents in the region have entrenched dependence on wells and boreholes for the provision of water supplies (Gbadegesin & Olorundemi, 2007; Abaje et al., 2009). Relying on these alternatives will be more cost-effective than desalination.

5. Conclusion and Recommendations

Inadequate access to potable water is a critical development challenge confronting most SSA countries. Access to potable water in many SSA countries is by no means certain due to a variety of factors such as periodic droughts, limited availability of and pollution of available freshwater resources. Shortage of natural freshwater supply is very critical and constrains the sustenance of socio-economic growth and development in many parts of the region. Although desalination plants have been built in South Africa and construction of a new plant has been proposed in other countries such as Ghana and Namibia; the strategy cannot, at present, be used to deal with water shortages in all the countries of SSA. The many concerns of the desalination option impact negatively on the suitability of the option for water services delivery in the sampled countries except Cape Verde, Namibia, Cape Province (South Africa) and the

Niger Delta region of Nigeria. Solutions to the problems of water shortages in the region should be sought through the development of alternative freshwater sources and through improved management of available sources and maintenance of supply systems. Improved management of available sources and maintenance of supply systems, for instance, will spur growth in water supply sector. The recommendations listed below can assist these countries to achieve the long-term objective of accelerated increases in the level of access to potable water.

1) Prioritizing water services delivery

Governments in these SSA countries can prioritize water services delivery by providing the resources needed to provide essential infrastructures, establishing appropriate policies instruments, and ensuring the sustainability of water infrastructure.

2) Creating the necessary institutions and infrastructure

The lack of quality water infrastructure in most of these countries represents one of the most significant limitations to quality service delivery and achievement of the SDGs in the water supply sector of SSA. Inadequate and non-functional infrastructure constrains the quality and sustainability of water provision in both urban and rural areas in SSA. Infrastructure investments and maintenance are very essential for improved water services, especially in the rural and sparsely populated countries. It has been argued that underinvestment in water infrastructure largely accounted for the under-performance in the water sector of SSA between 1990 and 2005 and that increased investments are still needed to spur growth and tackle water poverty in the region.

3) Adopting appropriate water supply policies

Policy instruments are needed to reinvigorate the water supply landscape in the region. The challenges limiting service delivery such as system failures, poor performance of water infrastructures, inadequate community participation, lack of costs recovery and failures of interventions programmes put in place to boost supply services, etc., can all be tackled through policy instruments.

4) Providing Post construction support

Post-Construction Support (PCS) enhances the quality and sustainability (regular, reliable supply) of water supply services. Support to Service Providers (SPs) is essential to correct present and future problems (Lockwood, 2002). Governments in the sampled countries may accelerate progress if they focus more on both the growth of water infrastructure as well as on the sustainability of the facilities. The countries need to provide the legislative, policy, and institutional framework on which service providers (SPs) can build and sustain rural water services delivery.

5) Developing Alternative Cheaper Sources

The cumulative costs of desalinating salty water are generally higher than the costs of developing alternatives such as abstraction freshwater from rivers, groundwater aquifers,

water recycling, water conservation, and rainwater harvesting. Relying on these alternatives may be more cost-effective than desalination.

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